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LOCAL FORECAST STUDIES—SUMMER RAINFALL.

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SYNOPSIS.

Observations at Dubuque, Iowa, at 7 a. m., 90th meridian time, for June and July, for the 20-year period, 1901 to 1920, inclusive, are tabulated with reference to the occurrence of precipitation within the following 12 and 24 hours, and classified according to the following elements:

a. Height of barometer, reduced to sea level.
b. Change in height of barometer during past 12 hours.
c. Change in temperature during past 24 hours.
d. Amount of cloudiness.
e. Relative humidity.

A further classification according to (*a*) wind direction, and (*b*) kind of clouds is based on a 30-year period for the four months, May to August, inclusive.

The results are shown in a series of tables and curves, based on the relation which the number of observations followed by rain within 12 or 24 hours bears to the total number of observations within the group. These tables and curves are intended to show the more important relationships existing between the data of the morning observation and the rain frequency during the following 12 and 24 hours, and it is suggested that a series of simple classifications, such as these, could be made at numerous stations throughout the United States, and would furnish material of much value.

Attention has frequently been called to the possibility of making use of local observational data as an aid to forecasting, and Bruno Rolf in Sweden has attained some success in developing a formula to express the probability of rain as deduced from local conditions.[1]

Without having seen more than a brief summary of his paper, the present study was begun as a preliminary attempt to devise a practical and simple method of making a statistical statement of the probability of rain from local conditions obtaining at the time of the regular morning observations of the Weather Bureau.

Observations at 7 a. m., 90th meridian time, at Dubuque, Iowa, for June and July for the 20-year period, 1901 to 1920, inclusive, were tabulated with reference to the occurrence of precipitation within the following 12 and 24 hours. The observations were then classified according to the following elements:

a. Height of barometer, reduced to sea level.
b. Change in height of barometer during past 12 hours.
c. Change in temperature during past 24 hours.
d. Amount of cloudiness.
e. Relative humidity.

[1] R. H. Weightman, MO. WEATHER REV., Mar., 1920, 48: 154-156.

The results are depicted in a series of curves, showing the relation, expressed as a percentage, which the number of observations followed by rain in 12 or 24 hours bears to the total number of observations within the group. A total of 1,217 observations is listed, but the number falling under extreme conditions is small, so that only the three or four central points of the curves are based upon a sufficient number of observations to eliminate in a fair degree the effects of chance. But these are the most important, of course, not only because of their much more frequent occurrence but also because the forecasts are more doubtful under these ordinary conditions than under extreme conditions.

The total probability of rain in 12 hours under all conditions is 0.31. The "All observations" curve in figure 1 shows that when the barometer is under 29.75 inches this rises to 0.62, and when the barometer is over 30.25 it falls to 0.06. When the barometer is falling the probability is increased by about 10 points, except when the barometer is high, and then it seems less likely to rain with falling than with rising pressure. When the morning observation shows a cloudy sky as well as a falling barometer the chances of rain in 12 hours are increased by from 20 to 40 points, and range from 83 per cent with a low barometer to 33 per cent with a high barometer.

I use the terms falling and rising barometer as indicating the change in 12 hours, and falling and rising temperature for the 24-hour change. The average barometric reading at the morning observation was found to be 0.055 inch higher than at the evening observation. This was taken as the value of the diurnal change, and a rise of 0.05 inch or less was classed as a falling barometer.

With increasing subdivision the results become more doubtful, but the greatest probability of rain is indicated when the sky is cloudy, the barometer falling, and the temperature also falling. Fifteen observations under these conditions with the barometer between 29.75 and 29.85 gave rain in 93 per cent of the cases, while 24 observations under the same conditions except that the temperature was rising gave a percentage of 62. The same general relation holds for all groups with the barometer below 30.05, but when the pressure rises above that point the position of the lines is reversed, and it seems more likely to rain with rising temperature. I can not say whether or not these results are consistent with the experience of forecasters.

CORRIGENDA.

In the Annual Index to the MONTHLY WEATHER REVIEW for 1920, the following corrigenda were inadvertantly omitted:
February REVIEW, back cover, data for January, 1920.
May REVIEW, back cover, data for March and April, 1920.
August REVIEW, back cover, data for May and July, 1920.
November REVIEW, back cover, data for October, 1920.

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The least probability of rain is also connected with falling temperature, but accompanied by clear weather and a rising barometer, as shown by the lowest curve in figure 1. Under these conditions for all barometric readings above 30 inches it has rained in less than 5 per cent of the cases, and for readings above 30.20 inches it has never rained.

Figure 2, giving the same analysis for rain in 24 hours, shows practically identical relations, with all percentages somewhat higher, of course, but not higher with reference to the total probability of rain, which is here 0.46 instead of 0.31.

In figures 3 and 4 the classification is based upon the amount of change in pressure during the preceding 12 hours. The probability for all observations decreases rapidly from a practical certainty of rain when the fall has been a quarter of an inch, to 12 or 13 per cent in 12 hours and 26 per cent in 24 hours when there has been a rise of a quarter of an inch. The probability is increased considerably for all groups, except where it is already a certainty, if the weather is also cloudy at observation, and decreased if it is clear. As in the previous computation, the probability is also increased with falling temperature when the weather is cloudy and decreased slightly with falling temperature when the sky is clear.

In figures 5 and 6 the abscissæ are again changes in barometric height, and the same "All observations" curve is shown as in figures 3 and 4. The other curves that are closely grouped about the average show the probability of rain with falling and with rising temperature, and with temperature above and below normal. We conclude from the fact that they follow the "All observations" curve so closely that, whether the temperature is falling or rising, whether it is above or below normal, gives very little indication of the probability of rain.

The shorter upper and lower curves in these figures show a considerable increase in rain probability with high humidity and a rather less-marked decrease with low humidity. The average humidity at the morning observation at Dubuque is 78 per cent. It will be recognized that the use of the morning humidity data for any purposes of forecasting is complicated by the fact that at times we do not in reality obtain free-air humidities, but record purely local conditions arising from surface radiation and light wind movement. Hence morning humidities do not bear a very close relation to subsequent rainfall. Tables 1 and 2 give in detail the data upon which all these curves are based.

In the foregoing discussion two important observational facts affecting the probability of rain have not been considered. These are wind direction and kind of clouds. Because of the increased subdivision made necessary by the consideration of these factors, it seemed best to tabulate a larger number of observations, and, accordingly, the morning observations were listed for May, June, July, and August from July, 1889, to August, 1920, inclusive, except 1895 and a portion of 1894, during which observations were missing. A total of about 3,500 observations was tabulated with the results shown in Tables 3 and 4. Table 3 gives separately for four barometric levels, and for falling and rising barometer, the total number of observations with clear, partly cloudy and cloudy sky for each of eight wind directions, also the number followed by rain in 12 and in 24 hours, the "expected number," and the percentage which the number with rain bears to the total number. Table 4 is the same except that cloud classification is substituted for wind direction.

The "expected number"[1] is the number to be expected on the assumption that the rainfall is independent of wind direction, or of kind of clouds. It is obtained by apportioning the total number of observations with rain to the different wind directions or cloud forms in the ratio which the number of observations in that group bears to the total number of observations. An example will make this clear. In Table 3 with barometer 29.94 or under and falling, the total number of observations is 707, the number with rain in 12 hours is 395, and the total from the north is 34. The "expected number" is then obtained from the equation

$$34 : 707 = x : 395, \text{ from which } x = 19.0$$

A comparison of the "expected number" with the actual number of rainy days, 14 in this case, shows at a glance whether the wind direction or cloud form is wetter or drier than the average. An "expected number" greater than the recorded number means that rains are less frequent than the average, as with the north wind, in this example, which is a dry wind.

We may note in Table 3 that with the barometer under 29.94 and falling, it will rain within 12 hours in 56 per cent of the cases, and within 24 hours in 69 per cent; but under the same barometric conditions and with an east wind and a cloudy sky at the morning observation, it will rain within 12 hours 88 per cent of the time, and within 24 hours 95 per cent. This is the case in which there is the greatest probability of rain, but under similar conditions with a northeast wind the probability is nearly as great. On the other hand, with the barometer over 30.15 and rising, out of 143 observations in which the wind was north, northeast, or east and the sky clear, it has never rained within 12 hours, and only 17 times, 12 per cent, within 24 hours. In these two cases definite forecasts could be made without the aid of a weather map. Other cases are intermediate, of course, but used in connection with the weather map will give some indication of the probability of showers.

The percentages of totals given at the bottom of Table 3 are shown graphically in figure 7, and we see that with a falling barometer the winds which are the best indicators of rain are northeast, east, southeast, and south, east showing the greatest percentage. When the barometer is rising, south and southwest winds show the greatest probability of rain; even with a west wind rain is as probable as with east and southeast.

Figure 8 gives a similar summary representation of Table 4. The first fact noted will be that the stratified clouds, except cirro-stratus, are the best indicators of rain, the percentage varying inversely with the height, i. e., decreasing in the order, stratus, strato-cumulus, alto-stratus. When the barometer is rising alto-cumulus displaces alto-stratus for third position, but with falling barometer it drops distinctly lower. When the barometer is falling, cirro-cumulus clouds rank very low for the 12-hour period, but high for the 24-hour period. Hence, when cirro-cumuli are observed with a falling barometer at the morning observation, one can say that it very probably will not rain during the day, but very probably will rain during the following night. In the case of cirro-stratus with rising pressure the curves for 12-hour and 24-hour rain frequency show a similar, though less pronounced, divergence of trend. The absence of morn-

[1] Chapman, E. H., *Quart. Jour. Roy. Met. Soc.*, 1914, 40: 349.

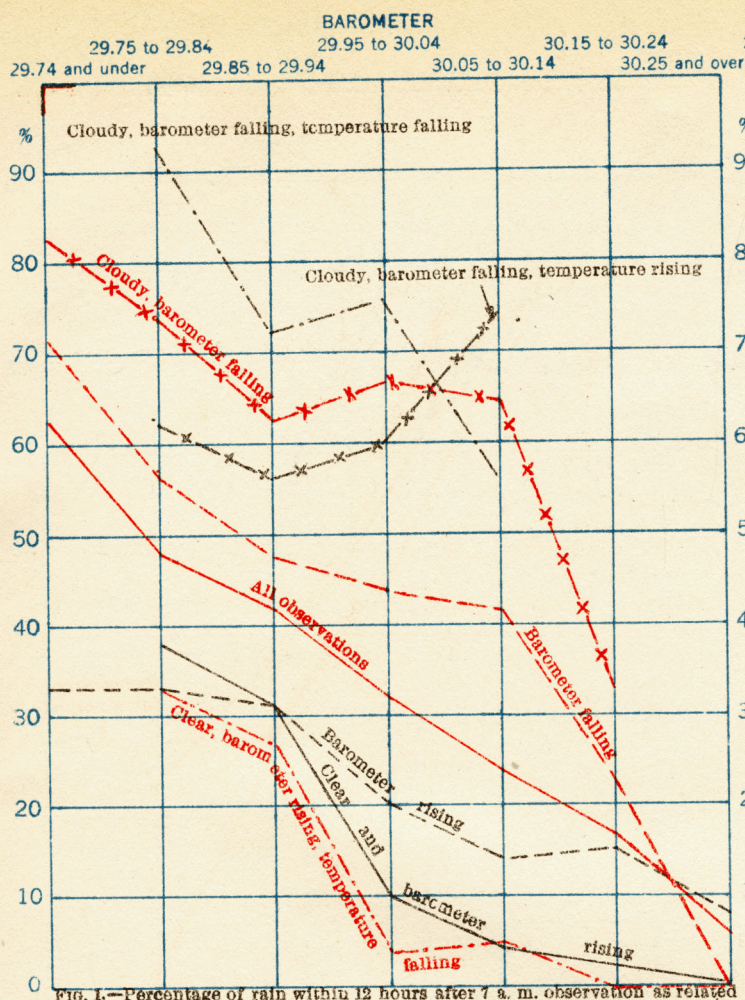


FIG. 1.—Percentage of rain within 12 hours after 7 a. m. observation as related to height of barometer and other factors.

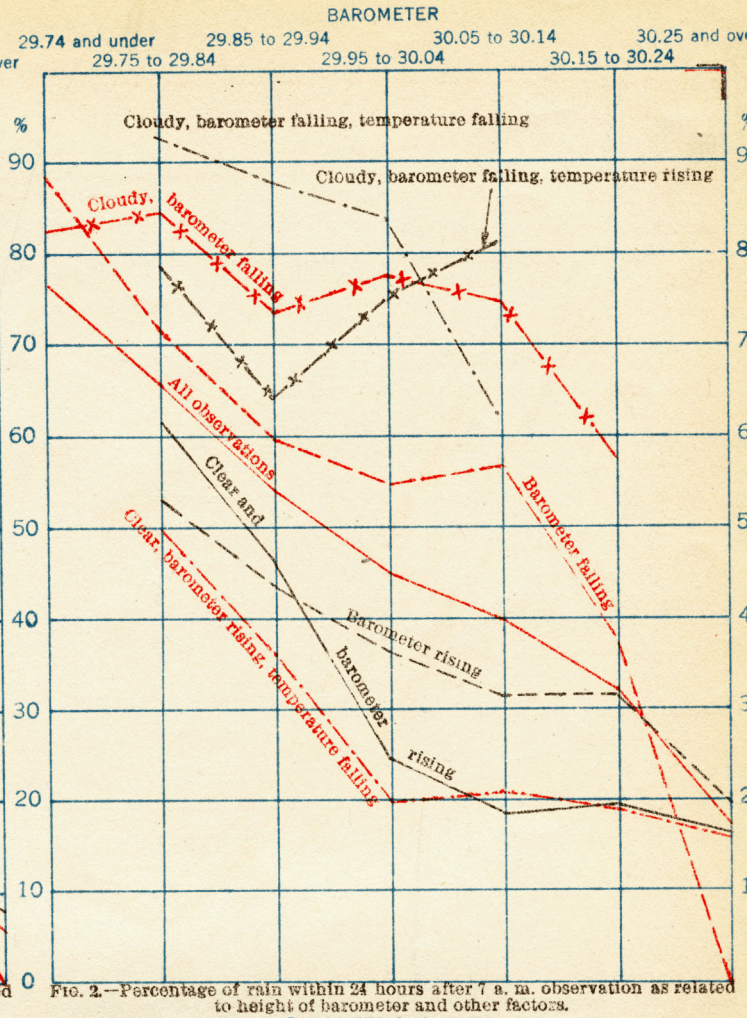


FIG. 2.—Percentage of rain within 24 hours after 7 a. m. observation as related to height of barometer and other factors.

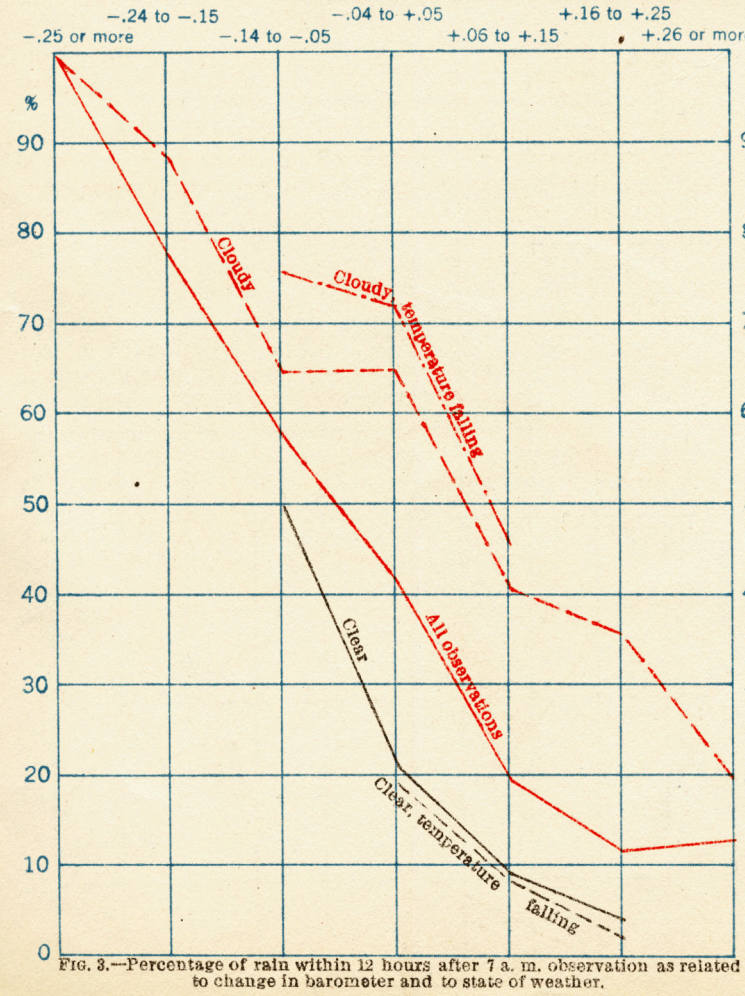


FIG. 3.—Percentage of rain within 12 hours after 7 a. m. observation as related to change in barometer and to state of weather.

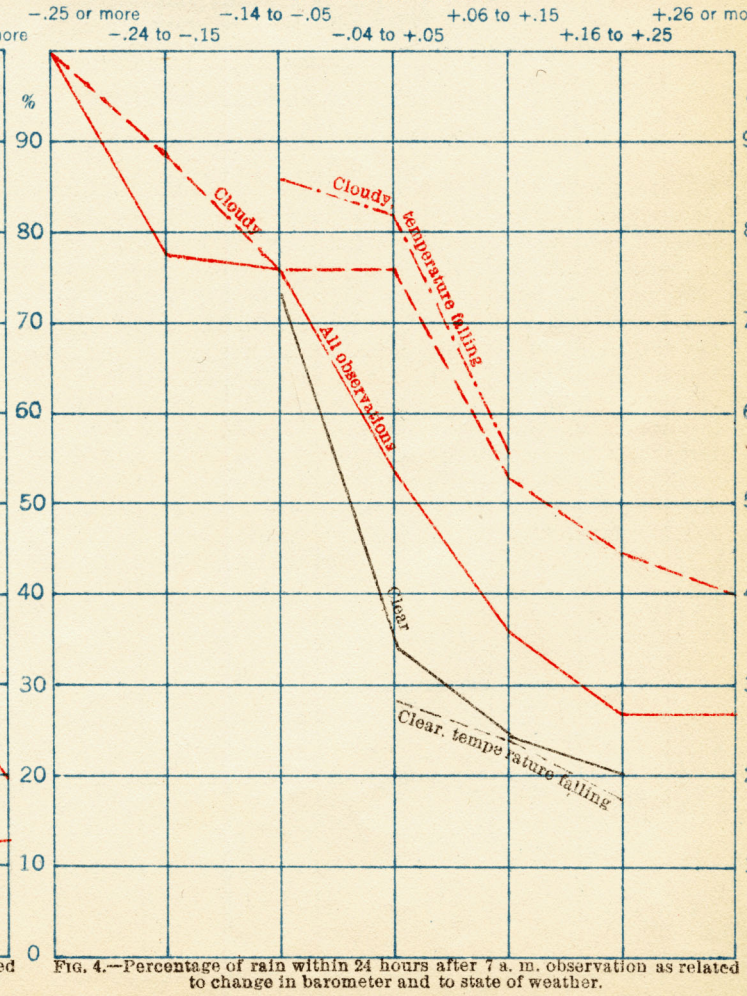


FIG. 4.—Percentage of rain within 24 hours after 7 a. m. observation as related to change in barometer and to state of weather.

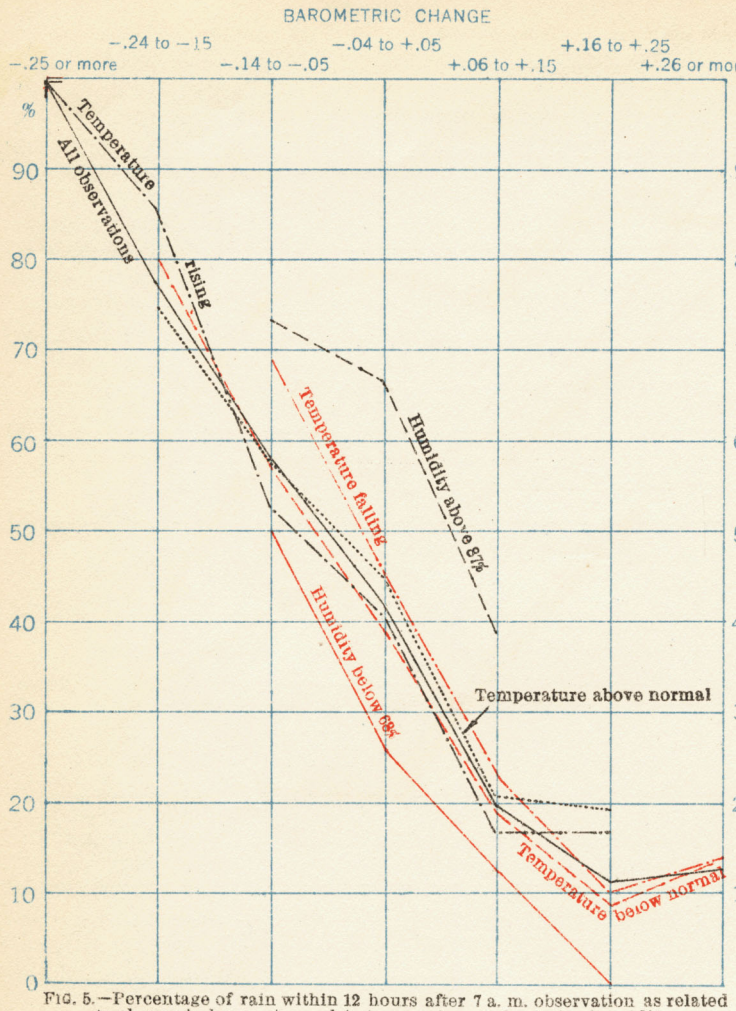


FIG. 5.—Percentage of rain within 12 hours after 7 a. m. observation as related to change in barometer and to temperature and relative humidity.

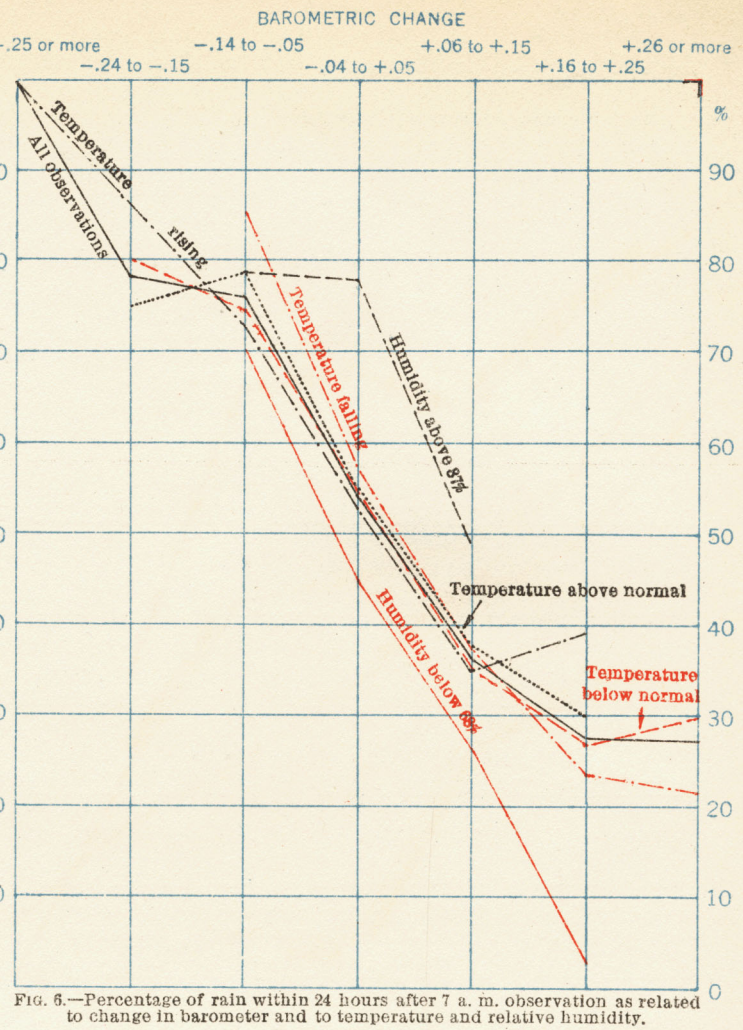
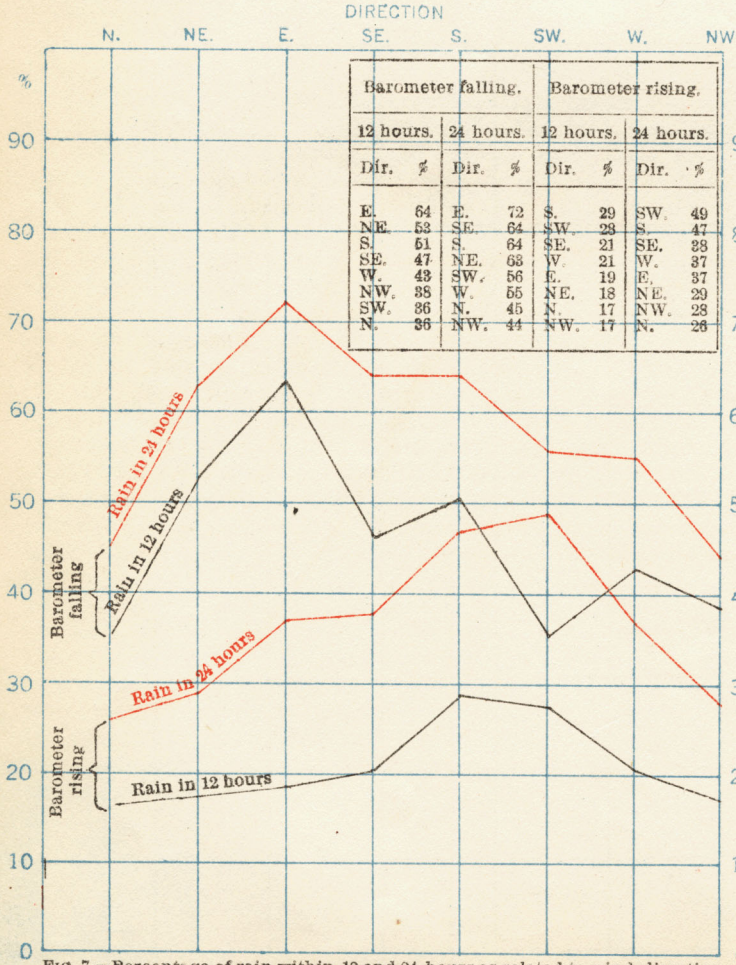
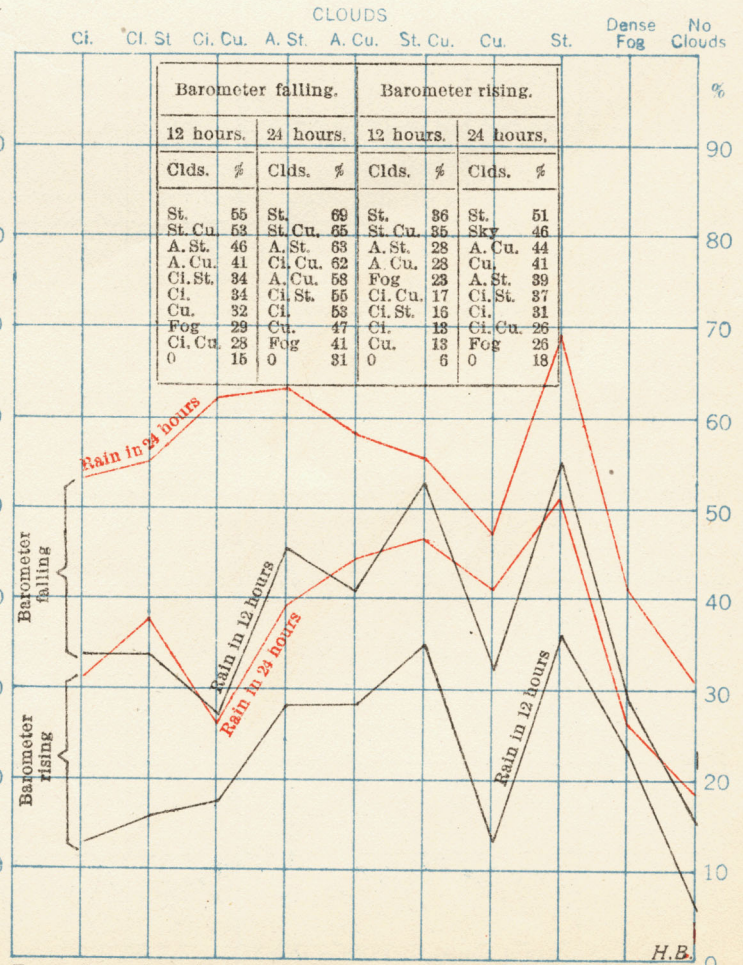


FIG. 6.—Percentage of rain within 24 hours after 7 a. m. observation as related to change in barometer and to temperature and relative humidity.



Barometer falling.				Barometer rising.			
12 hours.		24 hours.		12 hours.		24 hours.	
Dir.	%	Dir.	%	Dir.	%	Dir.	%
E.	64	E.	72	S.	29	SW.	49
NE.	53	SE.	64	SW.	28	S.	47
S.	51	S.	64	SE.	21	SE.	38
SE.	47	NE.	63	W.	21	W.	37
W.	43	SW.	56	E.	19	E.	37
NW.	38	W.	55	NE.	18	NE.	29
SW.	36	N.	45	N.	17	NW.	28
N.	36	NW.	44	NW.	17	N.	26

FIG. 7.—Percentage of rain within 12 and 24 hours as related to wind direction. Based on 3,390 observations at Dubuque Iowa.



Barometer falling.				Barometer rising.			
12 hours.		24 hours.		12 hours.		24 hours.	
Clds.	%	Clds.	%	Clds.	%	Clds.	%
St.	55	St.	69	St.	36	St.	51
St. Cu.	53	St. Cu.	65	St. Cu.	35	Sky	46
A. St.	46	A. St.	63	A. St.	28	A. Cu.	44
A. Cu.	41	Ci. Cu.	62	A. Cu.	28	Cu.	41
Ci. St.	34	A. Cu.	58	Fog	28	A. St.	39
Ci.	34	Ci. St.	55	Ci. Cu.	17	Ci. St.	37
Cu.	32	Ci.	53	Ci. St.	16	Ci.	31
Fog	29	Cu.	47	Ci.	13	Ci. Cu.	26
Ci. Cu.	28	Fog	41	Cu.	13	Fog	26
0	15	0	31	0	6	0	18

FIG. 8.—Percentage of rain within 12 and 24 hours as related to kind of clouds. Based on 3,400 observations at Dubuque, Iowa.

ing clouds is the best indication that there will be no rain, but it is by no means a certain indication, and with a low barometer there will be showers within 12 hours on one-fifth of the days. The presence of cumulus clouds, occurring most frequently in amounts of from one to three tenths, does not add greatly to the probability of rain. The number of dense fogs recorded is small, but only when the barometer is low do they seem to offer any indication of rain. These are a few of the facts indicated by the tables and figures. A detailed study will reveal many others.

Finally, figure 9 represents in a manner similar to figure 1, the percentage of rain frequency associated with certain wind directions when the sky is overcast by stratus or strato-cumulus clouds. We note here in curves B and B′ and E and E′ that when the barometer is between 29.95 and 30.14 and the wind southeast or south, there is a greater tendency to rain with a rising than with a falling barometer. Curves B′ and E′, however, are based on a small number of cases, and hence are subject to some doubt. A complete presentation of the details of Tables 3 and 4 would require 480 curves of this kind, but many points in these curves would be based on too few observations to be significant.

In this study I have attempted to show the more important relationships existing during the summer months in northeastern Iowa between the data of the morning observation and the frequency of rain during the following 12 and 24 hours. In these months the precipitation is mostly in the form of thundershowers, and the correlation of rainfall with other elements is probably less marked than in the winter months. No attempt has been made to combine all the observed conditions into a single mathematical expression for calculating directly the actual probability at any given time. It is a complex matter, and any formula of value would need to rest upon more than a single series of observations at one station. It is thought, however, that a series of simple, nonmathematical classifications, such as I have attempted, could be easily made at numerous stations throughout the United States, and would furnish material of much value, from which, possibly, precepts of general, or at least wide, application could be deduced. It is not assumed that such results would displace synoptic charts in forecasting, but that they would furnish valuable aid to the forecaster, and especially to the local official in making definite forecasts for short periods in advance.

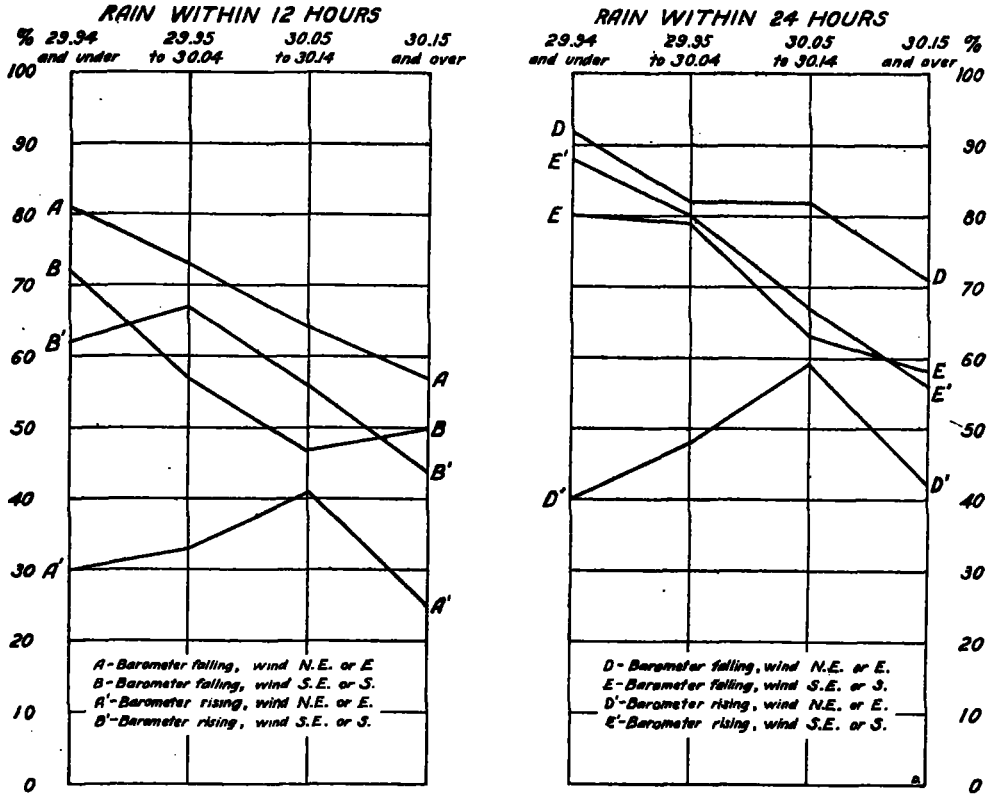


FIG. 9.—Relation between pressure, barometric tendency, wind direction, and subsequent rainfall at Dubuque, Iowa.

TABLE 1.—*Summer rainfall at Dubuque, Iowa, as related to height of barometer and other factors, based on observations at 7 a. m., 90th meridian time, for June and July for the years 1901 to 1920, inclusive—Total number of observations, 1,217.*

Height of barometer reduced to sea level.	29.74 and under.	29.75 to 29.84	29.85 to 29.94	29.95 to 30.04	30.05 to 30.14	30.15 to 30.24	30.25 or over.
All observations:							
Total number of observations	52	95	218	339	304	160	49
Number with rain, 12 hours	33	46	91	109	74	27	3
Percentage of total	63	48	42	32	24	17	6
Number with rain, 24 hours	40	63	117	154	122	52	9
Percentage of total	77	66	54	45	40	32	20
Barometer rising:							
Total	12	30	83	166	195	121	40
Rain, 12 hours	4	10	26	33	28	18	3
Percentage	33	33	31	20	14	15	8
Rain, 24 hours	5	16	36	59	60	37	9
Percentage	42	53	43	36	31	31	22
Clear, barometer rising, temperature falling:							
Total	2	6	22	46	61	37	19
Rain, 12 hours	0	2	6	2	3	0	0
Percentage	.....	33	27	4	5	.....	.....
Rain, 24 hours	0	3	8	9	13	7	3
Percentage	.....	50	36	20	21	19	16
Barometer falling:							
Total	40	65	135	173	109	39	9
Rain, 12 hours	29	36	65	76	46	9	0
Percentage	72	57	48	44	42	23	.....
Rain, 24 hours	35	47	81	95	62	15	0
Percentage	88	72	60	55	57	38	.....
Cloudy, barometer falling:							
Total	29	39	65	78	40	12	1
Rain, 12 hours	24	29	41	52	26	4	0
Percentage	83	74	63	67	65	33	.....
Rain, 24 hours	24	33	48	61	30	7	0
Percentage	83	85	74	78	75	58	.....
Cloudy barometer falling, temperature falling:							
Total	11	15	25	25	13	1	1
Rain, 12 hours	9	14	18	19	6	0	0
Percentage	82	93	72	76	46	.....	.....
Rain, 24 hours	9	14	22	21	8	1	0
Percentage	82	93	88	84	62	100	.....
Cloudy, barometer falling, temperature rising:							
Total	17	24	39	55	27	11	.....
Rain, 12 hours	14	15	22	33	20	4	.....
Percentage	82	62	56	60	74	36	.....
Rain, 24 hours	14	19	25	41	22	6	.....
Percentage	82	79	64	75	81	55	.....

TABLE 2.—*Summer rainfall at Dubuque, Iowa, as related to change in height of barometer and other factors, based on observations at 7 a. m., 90th meridian time, for June and July for the years 1901 to 1920, inclusive—Total number of observations, 1,217.*

Twelve-hour change in barometer.	−0.25 or more.	−0.24 to −0.15	−0.14 to −0.05	−0.04 to +0.05	+0.06 to +0.15	+0.16 to +0.25	+0.26 or more.
All observations:							
Total number of observations	4	9	97	460	547	85	15
Number with rain, 12 hours	4	7	56	194	110	10	2
Percentage of total	100	78	58	42	20	12	13
Number with rain, 24 hours	4	7	74	250	195	23	4
Percentage of total	100	78	76	54	36	27	27
Clear:							
Total	.....	1	22	176	306	56	9
Rain, 12 hours	.....	0	11	37	28	2	1
Percentage	.....	.....	50	21	9	4	11
Rain, 24 hours	.....	0	16	59	73	11	2
Percentage	.....	.....	73	34	24	20	22
Clear, temperature falling:							
Total	.....	1	4	43	137	47	8
Rain, 12 hours	.....	0	1	8	11	1	0
Percentage	.....	.....	25	19	8	2	.....
Rain, 24 hours	.....	0	3	12	33	8	1
Percentage	.....	.....	75	28	24	17	12
Clear, temperature rising:							
Total	.....	.....	20	134	166	10	1
Rain, 12 hours	.....	.....	10	29	15	1	1
Percentage	.....	.....	50	22	9	10	100
Rain, 24 hours	.....	.....	13	47	39	3	1
Percentage	.....	.....	65	35	23	30	100
Cloudy:							
Total	4	9	63	188	143	22	5
Rain, 12 hours	4	8	41	123	58	8	1
Percentage	100	89	65	65	41	36	20
Rain, 24 hours	4	8	48	143	76	10	2
Percentage	100	89	76	76	53	45	40
Cloudy, temperature falling:							
Total	1	1	21	71	78	17	4
Rain, 12 hours	1	1	16	51	36	6	1
Percentage	100	100	76	72	46	35	25
Rain, 24 hours	1	1	18	58	42	7	1
Percentage	100	100	86	82	56	41	25
Cloudy, temperature rising:							
Total	3	7	43	119	67	5	1
Rain, 12 hours	3	6	27	73	24	2	0
Percentage	100	86	63	61	36	40	.....
Rain, 24 hours	3	6	31	86	35	3	1
Percentage	100	86	72	72	52	60	100
Temperature rising:							
Total	3	7	71	321	282	18	1
Rain, 12 hours	3	6	38	131	49	3	0
Percentage	100	86	53	41	17	17	.....
Rain, 24 hours	3	6	52	171	97	7	1
Percentage	100	86	73	53	34	39	100
Temperature falling:							
Total	1	2	26	139	265	67	14
Rain, 12 hours	1	1	18	63	61	7	2
Percentage	100	50	69	45	23	10	14
Rain, 24 hours	1	1	22	79	98	16	3
Percentage	100	50	85	57	37	24	21
Temperature above normal:							
Total	.....	4	43	239	249	20	1
Rain, 12 hours	.....	3	25	108	52	4	0
Percentage	.....	75	58	45	21	20	.....
Rain, 24 hours	.....	3	34	131	94	6	0
Percentage	.....	75	79	55	38	30	.....
Temperature below normal:							
Total	4	5	54	221	298	65	14
Rain, 12 hours	4	4	31	86	58	6	2
Percentage	100	80	57	39	19	9	14
Rain, 24 hours	4	4	40	119	101	17	4
Percentage	100	80	74	54	34	26	29
Humidity above 87 per cent:							
Total	4	6	39	105	88	15	1
Rain, 12 hours	4	6	29	70	34	6	1
Percentage	100	100	74	67	39	40	100
Rain, 24 hours	4	6	31	82	43	9	1
Percentage	100	100	79	78	49	60	100
Humidity below 68 per cent:							
Total	.....	2	10	77	88	24	6
Rain, 12 hours	.....	1	5	20	10	0	1
Percentage	.....	50	50	26	12	.....	17
Rain, 24 hours	.....	1	7	34	21	3	1
Percentage	.....	50	70	44	26	12	17

TABLE 3.—*Summer rainfall at Dubuque, Iowa, as related to wind direction, state of weather, barometric height, and barometric tendency. Based on observations at 7 a. m., ninetieth meridian time, for May, June, July, and August, for the years 1889 to 1920, inclusive, except 1894 and 1895.*

BAROMETER FALLING.

	N.				NE.				E.				SE.				S.				SW.				W.				NW.				Total barometer falling.
	Clear.	Partly cloudy.	Cloudy.	Total.	Clear.	Partly cloudy.	Cloudy.	Total.	Clear.	Partly cloudy.	Cloudy.	Total.	Clear.	Partly cloudy.	Cloudy.	Total.	Clear.	Partly cloudy.	Cloudy.	Total.	Clear.	Partly cloudy.	Cloudy.	Total.	Clear.	Partly cloudy.	Cloudy.	Total.	Clear.	Partly cloudy.	Cloudy.	Total.	
BAROMETER 29.94 INCHES AND UNDER (REDUCED TO SEA LEVEL).																																	
Total	7	4	23	34	1	5	29	35	6	3	40	49	13	27	87	127	34	37	109	180	44	30	48	122	17	7	30	54	36	18	52	106	707
Rain in 12 hours:																																	
Number	2	0	12	14	0	2	24	26	1	1	35	37	5	11	69	85	14	17	80	111	11	13	20	44	3	3	21	27	7	7	37	51	305
Expected number				19.0				19.6				27.4				70.9				10.05				68.1				31.2				59.2	
Per cent			52	41			83	74			88	76		41	79	67	41	46	73	62	25	43	42	36			70	50	19	39	71	47	56
Rain in 24 hours:																																	
Number	2	2	15	19	0	2	26	28	1	1	38	40	6	17	75	98	18	25	89	132	22	22	26	70	7	4	23	34	14	9	41	64	485
Expected number				23.3				24.0				33.6				87.1				123.5				83.7				37.0				72.7	
Per cent			65	56			90	80			95	82		63	86	77	53	68	82	73	56	73	54	57			77	63	39	50	79	60	69
BAROMETER 29.95 TO 30.04 INCHES (REDUCED TO SEA LEVEL).																																	
Total	8	6	15	29	6	4	19	29	5	4	22	31	32	25	63	120	32	23	52	107	30	15	25	70	9	9	8	26	28	10	21	59	471
Rain in 12 hours:																																	
Number	1	2	9	12	1	2	12	15	1	1	18	20	5	5	43	53	11	11	31	53	7	3	18	28	3	2	3	8	2	0	6	8	197
Expected number				12.1				12.1				13.0				50.2				44.7				29.3				10.9				24.7	
Per cent				41				52			82	65	16	20	68	44	34	48	60	50	23	20	72	40				31	7		29	14	42
Rain in 24 hours:																																	
Number	1	3	9	13	2	2	13	17	3	1	19	23	13	11	54	78	17	15	38	70	15	6	19	40	5	4	3	12	2	3	7	12	265
Expected number				16.3				16.3				17.4				67.6				60.2				39.4				14.6				33.2	
Per cent				45				39			86	74	41	44	86	65	53	65	73	65	50	40	76	57				46	7		33	20	56
BAROMETER 30.5 TO 30.14 INCHES (REDUCED TO SEA LEVEL).																																	
Total	12	2	13	27	5	1	8	14	5	1	17	23	37	21	43	101	32	16	25	73	15	7	7	29	7	2	5	14	12	4	9	25	306
Rain in 12 hours:																																	
Number	1	0	9	10	1	0	5	6	1	0	10	11	7	6	22	35	4	6	15	25	3	1	4	8	2	1	3	6	3	0	5	8	100
Expected number				9.6				5.0				8.2				36.0				26.0				10.3				5.0				8.9	
Per cent				37				43				48	19	28	51	35	12		60	34				28				43				32	36
Rain in 24 hours:																																	
Number	1	0	10	11	2	0	6	8	1	0	11	12	13	14	27	54	9	12	20	41	8	3	5	16	2	2	3	7	4	0	7	11	160
Expected number				14.1				7.3				12.0				52.8				38.2				15.2				7.3				13.1	
Per cent				41				37				52	35	67	63	53	28		80	56				55				50				44	52
BAROMETER 30.15 INCHES AND OVER (REDUCED TO SEA LEVEL).																																	
Total	12	1	4	17	10	3	8	21	9	3	9	21	18	7	21	46	11	5	5	21	6	8	4	18	1	0	1	2	8	2	3	13	159
Rain in 12 hours:																																	
Number	1	0	2	3	0	0	5	5	2	2	7	11	1	4	9	14	2	2	3	7	2	3	2	7	0	0	0	0	0	0	2	2	49
Expected number				5.2				6.5				6.5				14.1				6.5				5.5				0.6				4.0	
Per cent				18				24				52			43	30				33				39				0				15	31
Rain in 24 hours:																																	
Number	2	1	2	5	0	2	7	9	4	3	7	14	4	6	12	22	4	2	4	10	2	4	2	8	0	0	0	0	0	0	3	3	71
Expected number				7.6				9.4				9.4				20.6				9.4				8.0				0.9				5.5	
Per cent				29				43				67			57	48				48				44				0				23	45
Total:																																	
Total				107				99				124				394				381				239				96				203	1,643
Rain in 12 hours:																																	
Number				39				52				79				187				196				87				41				69	750
Expected number				44.8				45.2				56.6				179.9				173.8				109.1				43.8				92.7	
Per cent				36				53				64				47				51				36				43				36	46
Rain in 24 hours:																																	
Number				48				62				89				252				253				134				53				90	981
Expected number				63.9				59.1				74.0				235.3				227.5				142.7				57.3				121.2	
Per cent				45				63				72				64				64				56				55				44	60

TABLE 3.—*Summer rainfall at Dubuque, Iowa, as related to wind direction, state of weather, barometric height, and barometric tendency. Based on observations at 7 a. m., ninetieth meridian time, for May, June, July, and August, for the years 1889 to 1920, inclusive, except 1894 and 1895*—Continued.

BAROMETER RISING.

	N.				NE.				E.				SE.				S.				SW.				W.				NW.				Total barometer rising.	Grand total.
	Clear.	Partly cloudy.	Cloudy.	Total.	Clear.	Partly cloudy.	Cloudy.	Total.	Clear.	Partly cloudy.	Cloudy.	Total.	Clear.	Partly cloudy.	Cloudy.	Total.	Clear.	Partly cloudy.	Cloudy.	Total.	Clear.	Partly cloudy.	Cloudy.	Total.	Clear.	Partly cloudy.	Cloudy.	Total.	Clear.	Partly cloudy.	Cloudy.	Total.		
BAROMETER 29.94 INCHES AND UNDER (REDUCED TO SEA LEVEL).																																		
Total	12	15	18	45	1	2	7	10	1	2	3	6	13	6	14	33	16	11	13	40	26	11	12	49	12	7	21	40	45	21	46	112	335	1,042
Rain in 12 hours:																																		
Number	4	2	9	15	0	1	2	3	0	0	1	1	0	0	8	8	5	7	6	18	7	4	6	17	0	1	10	11	12	5	18	35	108	503
Expected number				14.5				3.2				1.9				10.6				12.9				15.8				12.9				36.1		
Per cent				33				30				17				24				45	27			35				48	28	27	24	39	31	32	46
Rain in 24 hours:																																		
Number	5	2	10	17	0	1	3	4	1	1	1	3	4	4	13	21	9	9	10	28	12	8	11	31	5	2	12	19	16	5	25	46	169	654
Expected number				22.7				5.0				3.0				16.6				20.2				24.7				20.2				56.5		
Per cent				38				40				50				64				70	46			63				57	48	36	24	54	41	50	63
BAROMETER 29.95 TO 30.04 INCHES (REDUCED TO SEA LEVEL).																																		
Total	27	14	20	61	11	4	20	35	9	3	17	29	29	11	12	52	20	9	14	43	23	8	10	41	18	5	5	28	80	17	26	123	412	883
Rain in 12 hours:																																		
Number	2	2	9	13	0	0	10	10	2	0	7	9	8	4	7	19	3	3	9	15	5	2	4	11	2	1	2	5	4	5	9	18	100	297
Expected number				14.8				8.5				7.0				12.6				10.4				10.0				6.8				29.9		
Per cent	7		45	21			50	29				31	28			37	15			35	22			27				18	5		35	15	24	34
Rain in 24 hours:																																		
Number	4	5	11	20	1	1	11	13	2	2	11	15	11	5	8	27	7	4	11	22	10	4	7	21	5	1	3	9	11	7	9	27	151	416
Expected number				22.4				12.8				10.6				19.1				15.8				15.0				10.3				45.1		
Per cent	15		55	33			55	37				52	38			46	35			51	43			51				32	14		35	22	37	47
BAROMETER 30.05 TO 30.14 INCHES (REDUCED TO SEA LEVEL).																																		
Total	41	11	19	71	33	10	18	61	18	10	15	43	47	18	21	86	24	7	14	45	14	2	9	25	11	8	7	26	98	25	21	144	501	807
Rain in 12 hours:																																		
Number	4	2	4	10	2	2	9	13	0	1	8	9	4	4	11	19	0	1	7	8	2	0	5	7	2	2	2	6	5	5	7	17	89	198
Expected number				12.6				10.8				7.6				15.3				8.0				4.4				4.6				25.6		
Per cent	10			14	6			21				21	9		52	22	0			18				28				23	5	20	33	12	18	25
Rain in 24 hours:																																		
Number	6	4	5	15	4	5	11	20	2	2	10	14	10	10	15	35	4	4	8	16	3	1	7	11	2	2	2	6	20	9	8	37	154	314
Expected number				21.8				18.7				13.2				36.4				13.8				7.7				8.0				44.2		
Per cent	15			21	12			33				33	21		71	41	17			36				44				23	20	36	38	26	31	39
BAROMETER 30.15 INCHES AND OVER (REDUCED TO SEA LEVEL).																																		
Total	73	9	16	98	40	18	20	78	36	18	10	64	68	13	23	104	22	2	9	33	13	3	4	20	11	2	2	15	62	9	16	87	499	658
Rain in 12 hours:																																		
Number	0	1	7	8	0	1	7	8	0	3	5	8	3	2	7	12	0	0	6	6	2	0	1	3	0	0	1	1	1	3	5	9	55	104
Expected number				10.8				8.6				7.0				11.4				3.6				2.2				1.6				9.6		
Per cent	0			8	0		35	10	0			12	4		30	12	0			18				15				7	2			10	11	16
Rain in 24 hours:																																		
Number	9	3	8	20	3	4	10	17	5	9	7	21	13	3	9	25	3	0	7	10	2	0	1	3	4	1	1	6	10	4	6	20	122	193
Expected number				23.9				19.0				15.6				25.4				8.1				4.9				3.7				21.2		
Per cent	12			20	8		50	22	17			33	19		39	24	14			30				15				40	16			23	24	29
Totals:																																		
Total				275				184				142				275				161				135				109				466	1,747	3,390
Rain in 12 hours:																																		
Number				46				34				27				58				47				38				23				79	352	1,102
Expected number				55.4				37.1				28.6				55.4				32.4				27.2				22.0				93.9		
Per cent				17				18				19				21				29				28				21				17	20	33
Rain in 24 hours:																																		
Number				72				54				53				105				76				66				40				130	596	1,577
Expected number				93.8				62.8				47.4				93.8				54.9				46.1				37.2				159.0		
Per cent				26				29				37				38				47				49				37				28	34	47

TABLE 4.—*Summer rainfall at Dubuque, Iowa, as related to kind and amount of cloudiness, and to barometric height and barometric tendency—Based on observations at 7 a. m., 90th meridian time, for May, June, July, and August, for the years 1889 to 1920, inclusive, except 1894 and 1895.*

BAROMETER FALLING.

	Ci.				Ci.St.				Ci.Cu.				A.St.				A.Cu.				St.Cu.				Cu.				St				Dense fog.	No clouds (including few and light fog).	Total, barometer falling.
	1-3	4-7	8-10	Total.	1-3	4-7	8-10	Total.	1-3	4-7	8-10	Total.	1-3	4-7	8-10	Total.	1-3	4-7	8-10	Total.	1-3	4-7	8-10	Total.	1-3	4-7	8-10	Total.	1-3	4-7	8-10	Total.			
BAROMETER 29.94 INCHES AND UNDER (REDUCED TO SEA LEVEL).																																			
Total	31	8	0	39	69	35	5	109	11	2	0	13	46	30	23	99	25	13	0	38	16	29	46	91	30	10	4	44	40	37	200	277	9	77	796
Rain in 12 hours:																																			
Number	16	4	0	20	26	19	3	48	3	0	0	3	22	12	14	48	12	7	0	19	6	17	34	57	11	2	1	14	14	19	131	164	5	16	394
Expected number				19.3				54.0				6.4				49.0				18.8				45.0				21.8				137.1	4.5	38.1	
Per cent	52			51	38	54		44				23	48	40	61	48	48			50		59	74	63	37			32	35	51	66	59	56	21	49
Rain in 24 hours:																																			
Number	18	7	0	25	39	24	5	68	8	0	0	8	29	18	16	63	16	11	0	27	8	19	38	65	13	5	1	19	26	24	148	198	7	34	514
Expected number				25.2				70.4				8.4				64.0				24.5				58.8				28.4				178.9	5.8	49.7	
Per cent	58			64	57	69		62				62	63	60	70	64	64			71		66	83	71	43			43	65	65	74	71	78	44	65
BAROMETER 29.95 TO 30.04 INCHES (REDUCED TO SEA LEVEL).											4																								
Total	34	7	2	43	38	34	1	73	7	3	0	10	35	24	15	74	15	6	2	23	11	18	28	57	24	5	3	32	25	17	97	139	3	82	536
Rain in 12 hours:																																			
Number	8	2	1	11	11	11	0	22	1	1	0	2	15	9	12	36	6	0	0	6	8	6	14	28	9	1	0	10	5	10	55	70	0	11	196
Expected number				15.7				26.7				3.7				27.1				8.4				20.9				11.7				50.9	1.1	30.0	
Per cent	24			26	29	32		30				20	43	38		49				26			50	49	38			31	20		57	50	0	13	37
Rain in 24 hours:																																			
Number	17	6	1	24	18	17	0	35	4	3	0	7	24	12	12	48	7	0	1	8	9	7	19	35	15	2	0	17	11	11	69	91	0	23	288
Expected number				23.1				39.2				5.4				39.7				12.4				30.6				17.2				74.6	1.6	44.0	
Per cent	50			56	47	50		48				70	69	50		65				35			68	61	62			53	44		71	65	0	28	54
BAROMETER 30.05 TO 30.14 INCHES (REDUCED TO SEA LEVEL).																																			
Total	21	4	0	25	30	16	3	49	11	1	1	13	15	9	10	34	7	6	0	13	10	13	12	35	5	5	3	13	7	12	57	76	3	83	344
Rain in 12 hours:																																			
Number	6	0	0	6	6	5	0	11	3	1	0	4	4	5	3	12	1	4	0	5	2	5	7	14	2	2	1	5	3	5	28	36	0	12	105
Expected number				7.6				14.9				4.0				10.4				4.0				10.7				4.0				23.2	0.9	25.3	
Per cent	29			24	20			22				31				35				38				40				38			49	47	0	14	31
Rain in 24 hours:																																			
Number	7	2	0	9	11	11	0	22	6	1	0	7	8	8	5	21	2	4	0	6	3	8	9	20	2	3	1	6	5	8	38	51	0	25	167
Expected number				12.1				23.8				6.3				16.5				6.3				17.0				6.3				36.9	1.5	40.2	
Per cent	33			36	37			45				54				62				46				57				46			67	67	0	30	49
BAROMETER 30.15 INCHES AND OVER (REDUCED TO SEA LEVEL).																																			
Total	11	1	0	12	24	11	2	37	3	1	0	4	7	5	10	22	7	7	0	14	3	1	6	10	0	2	2	4	7	4	20	31	2	52	188
Rain in 12 hours:																																			
Number	2	1	0	3	8	2	1	11	1	1	0	2	3	1	6	10	2	4	0	6	0	1	2	3	0	0	1	1	5	1	11	17	0	4	57
Expected number				3.6				11.2				1.2				6.7				4.2				3.0				1.2				9.4	0.6	15.8	
Per cent				25	33			30				50				45				43				30				25			55	55	0	8	30
Rain in 24 hours:																																			
Number	4	1	0	5	15	6	1	22	2	1	0	3	3	3	7	13	4	6	0	10	1	1	3	5	0	0	2	2	5	1	13	19	0	8	87
Expected number				5.6				17.1				1.9				10.2				6.5				4.6				1.9				14.4	0.9	24.1	
Per cent				42	62			59				75				59				71				50				50			65	61	0	15	46
Totals:																																			
Total				119				288				40				229				88				193				93				523	17	294	1,864
Rain in 12 hours:																																			
Number				40				92				11				106				36				102				30				287	5	43	752
Expected number				48.0				108.0				16.1				92.3				35.5				77.8				37.5				210.8	6.8	118.5	
Per cent				34				34				28				46				41				53				32				55	29	15	40
Rain in 24 hours:																																			
Number				63				147				25				145				51				125				44				359	7	90	1,056
Expected number				67.5				152.0				22.7				129.8				49.9				109.4				52.7				296.5	9.7	166.7	
Per cent				53				55				62				63				58				65				47				69	41	31	57

TABLE 4.—*Summer rainfall at Dubuque, Iowa, as related to kind and amount of cloudiness, and to barometric height and barometric tendency—Based on observations at 7 a. m., 90th meridian time, for May, June, July, and August, for the years 1889 to 1920, inclusive, except 1894 and 1895*—Continued.

BAROMETER RISING.

	Ci.				Ci.St.				Ci.Cu.				A.St.				A.Cu.				St.Cu.				Cu.				St.				Dense fog.	No clouds (including "few" and light fog).	Total, barometer rising.	Grand total.
	1-3	4-7	8-10	Total.	1-3	4-7	8-10	Total.	1-3	4-7	8-10	Total.	1-3	4-7	8-10	Total.	1-3	4-7	8-10	Total.	1-3	4-7	8-10	Total.	1-3	4-7	8-10	Total.	1-3	4-7	8-10	Total.				
BAROMETER 29.94 INCHES AND UNDER (REDUCED TO EA LEVEL).																																				
Total	18	4	0	22	30	23	4	57	8	0	0	8	25	13	10	48	10	4	0	14	11	13	9	33	9	3	5	17	16	25	76	117	3	74	393	1,189
Rain in 12 hours:																																				
Number	4	1	0	5	5	5	2	12	0	0	0	0	5	6	2	13	5	0	0	5	5	4	7	16	1	1	1	3	8	10	33	51	2	13	120	514
Expected number				6.7				17.4				2.4				14.6				4.3				10.1				5.2				35.7	0.9	22.6		
Per cent				23	17	22		21				0	20			27				36				48				18		40	43	44	67	18	31	43
Rain in 24 hours:																																				
Number	9	2	0	11	13	8	3	24	0	0	0	0	5	9	5	19	7	1	0	8	7	6	7	20	5	2	2	9	10	12	47	69	3	27	190	704
Expected number				10.6				27.5				3.9				23.2				6.8				15.9				8.2				56.5	1.4	35.7		
Per cent				50	43	35		41				0	20			40				57				61				53		48	62	59	100	36	48	59
BAROMETER 19.95 TO 30.04 INCHES (REDUCED TO SEA LEVEL).																																				
Total	28	4	1	33	53	28	4	85	3	4	0	7	26	15	9	50	11	5	1	17	15	8	13	36	10	2	2	14	20	14	60	94	9	123	468	1,004
Rain in 12 hours:																																				
Number	6	0	0	6	10	7	0	17	1	1	0	2	6	6	4	16	3	1	1	5	4	3	4	11	2	0	0	2	5	8	25	38	2	12	111	307
Expected number				7.8				20.1				1.7				11.8				4.0				8.5				3.3				22.3	2.1	29.2		
Per cent	21			18	19	25		20				29	23			32				29				31				14	25		42	40	22	10	24	31
Rain in 24 hours:																																				
Number	11	1	0	12	24	11	2	37	1	1	0	2	10	7	6	23	4	3	1	8	5	4	5	14	4	1	0	5	7	11	31	49	2	23	175	463
Expected number				12.3				31.8				2.6				18.7				6.4				15.5				5.2				35.2	3.4	46.0		
Per cent	39			36	45	39		44				29	38			46				47				39				36	35		52	52	22	19	37	46
BAROMETER 30.05 TO 30.14 INCHES (REDUCED TO SEA LEVEL).																																				
Total	38	4	0	42	52	42	3	97	16	2	0	18	23	11	14	48	15	5	1	21	10	14	12	36	9	3	4	16	21	17	60	98	8	192	576	920
Rain in 12 hours:																																				
Number	7	0	0	7	8	7	0	15	2	2	0	4	6	2	6	14	4	3	1	8	2	4	6	12	2	0	0	2	1	6	19	26	2	9	99	204
Expected number				7.2				16.7				3.1				8.3				3.6				6.2				2.8				16.9	1.4	33.0		
Per cent	18			17	15	17		15				22	26			29				38				33				12	5		32	27	25	5	17	22
Rain in 24 hours:																																				
Number	13	0	0	13	15	21	1	37	4	2	0	6	6	4	8	18	6	4	1	11	3	5	8	16	5	0	1	6	4	9	26	39	2	29	177	344
Expected number				12.9				29.8				5.5				14.7				6.4				11.1				4.9				30.1	2.5	58.9		
Per cent	34			31	29	50		38				33	26			38				52				44				38	19		43	40	25	15	31	37
BAROMETER 30.15 INCHE AND OVER (REDUCED TO EA LEVEL).																																				
Total	45	8	0	53	58	40	3	101	11	3	0	14	19	13	9	41	18	7	2	27	14	5	14	33	4	2	1	7	16	7	46	69	11	225	581	769
Rain in 12 hours:																																				
Number	1	0	0	1	4	6	2	12	1	1	0	2	2	3	4	9	1	3	0	4	5	1	3	9	0	0	0	0	2	1	18	21	1	3	62	119
Expected number				5.7				10.8				1.5				4.4				2.9				3.5				0.7				7.4	1.2	24.1		
Per cent	2			2	7	15		12				14				22				15				27				0			39	30	10	1	11	16
Rain in 24 hours:																																				
Number	9	2	0	11	15	10	2	27	3	1	0	4	4	4	5	13	3	5	0	8	7	2	4	13	2	0	0	2	8	3	23	34	1	31	144	231
Expected number				13.2				25.2				3.5				10.2				6.8				8.2				1.8				17.2	2.8	56.2		
Per cent	20			21	26	25		27				29				32				30				39				29			50	49	10	14	29	36
Totals:																																				
Total				150				340				47				187				79				138				54				378	31	614	2,013	3,882
Rain in 12 hours:																																				
Number				19				56				8				52				22				48				7				136	7	37	392	1,144
Expected number				29.1				66.0				9.1				36.3				15.3				26.8				10.5				73.3	9.0	119.1		
Per cent				13				16				17				28				28				35				13				36	23	6	19	29
Rain in 24 hours:																																				
Number				47				125				12				73				35				63				22				191	8	110	686	1,742
Expected number				51.0				115.6				16.0				63.6				26.9				46.9				18.4				128.5	14.0	208.8		
Per cent				31				37				26				39				44				46				41				51	26	18	34	45